



**WorleyParsons**

resources & energy

NETL's 2006 ENVIRONMENTAL CONTROLS CONFERENCE

# A NEW APPROACH FOR HYBRID SNCR/SCR FOR NO<sub>x</sub> REDUCTION

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- ▶ What is a “WorleyParsons”
- ▶ Location → Reading, PA
- ▶ If you are old → Gilbert Associates or Gilber/Commonwealth
- ▶ If you are middle age → Parsons → Parsons Energy & Chemicals (PEC)
- ▶ If you are young → an Australian engineering company specializing in the mining & oil industries brought PEC last year



- ▶ Introduction
- ▶ NOx Reduction Technology Review
- ▶ SCR Negative Impacts
- ▶ Hybrid SNCR/SCR
- ▶ Economics
- ▶ Summary
- ▶ Recommendation



► NO<sub>x</sub> Formation mechanisms

- Fuel NO<sub>x</sub> → reaction of chemically bound nitrogen in the coal with O<sub>2</sub> → ~70% of NO<sub>x</sub>
- Thermal NO<sub>x</sub> → combustion with an excess of O<sub>2</sub> → 30% of NO<sub>x</sub>
- Prompt NO<sub>x</sub> → interaction of molecular nitrogen with hydrocarbons

► NO<sub>x</sub> Composition

- NO → ~95%
- NO<sub>2</sub> → ~5%



- ▶ LNB – Low NOx Burners
- ▶ OFA – Over-fired Air
- ▶ SNCR – Selective Non-Catalytic Reduction
- ▶ SCR - Selective Catalytic Reduction
- ▶ Conventional approach → LNB with SCR



- ▶ Reduce the primary air to the coal burners
  - Reducing, fuel-rich atmosphere → coal-bound nitrogen converted to molecular N<sub>2</sub>
  - Reducing atmosphere has lower temperature → further reducing NO<sub>x</sub>
- ▶ Secondary air combusts remainder of coal in a fuel-lean zone → at a lower temperature
- ▶ Results → NO<sub>x</sub> down to < 0.5 lb/Mbtu, regardless of inlet NO<sub>x</sub>



- ▶ Reduces total secondary air the burners
- ▶ Part of increased secondary air to ports above the burners → 10% to 20% of SA
- ▶ Negative impacts
  - Increased LOI
  - Increased slagging
  - Increased corrosion
- ▶ Combination of LNB & OFA →  $\text{NO}_x < 0.4 \text{ lb/Mbtu}$



- ▶ Post-combustion, gas-phase reaction → optimum gas temperature 1700 F to 1900 F
- ▶ Trade-off between NO<sub>x</sub> removal & NH<sub>3</sub> slip
  - Below 1700 F → low NO<sub>x</sub> removal & high NH<sub>3</sub> slip
  - Above 1900 F → low NO<sub>x</sub> removal & low NH<sub>3</sub> slip
- ▶ Conventional operation above optimum (> 2,000 F) to minimize NH<sub>3</sub> slip
- ▶ NO<sub>x</sub> removal
  - Small boilers → up to 35%
  - Large boilers → up to 30%
- ▶ Most applications use a urea (ammonia carbonate) solution





- ▶ “selective” – only removes  $\text{NO}_2$  from nitrogen → not from carbon, sulfur or other oxygenated compounds
- ▶ Operation at ~650 with a vanadium/titanium catalyst → like a sulfuric acid catalyst
- ▶ SCR reactions
  - $\text{NH}_3$  diffuses to active sites in catalyst pore structure &  $\text{NH}_3$  is absorbed on active site
  - $\text{NO}$  reacts with  $\text{NH}_3$
  - Active site regenerated by oxidation
- ▶ Typically 4 catalyst layers for 90% removal with < 2 ppm  $\text{NH}_3$  slip (at end of catalyst life)



- ▶ Ammonia ( $\text{NH}_3$ ) slip → water soluble
  - ABS (ammonium bisulfate) formation in air heater
  - $\text{NH}_3$  ad/absorbed on fly ash & in FGD solution
- ▶ Increased  $\text{SO}_3$  emissions → doubles “boiler”  $\text{SO}_3$ 
  - Acid dew point (ADP) temperature increase
  - Plume opacity increase



► ABS Formation

- Gas phase reaction of  $\text{SO}_3$  &  $\text{NH}_3 \rightarrow$  temperature range form 330 F to 350 F
- Sticky solids formed in air heater
- With high-sulfur coals, measurable ABS deposits/pluggage in air heater above ~1.5 ppm  $\text{NH}_3$

►  $\text{NH}_3$  ad/absorption on fly ash

- Ash sluice – 1 ppm  $\text{NH}_3$  slip  $\rightarrow$  ~0.5 ppm in sluice water
- Dry ash – 1 ppm  $\text{NH}_3$  slip  $\rightarrow$  ~70 ppm on dry ash

► Byproduct ash sales – limited to ~100 ppm  $\text{NH}_3 \rightarrow$  generic “rule of thumb”, but reality may be lower



- ▶ Acid Dew Point (ADP) temperature increase
  - Low-sulfur units switching to high-sulfur coals with FGD & SCR → 30+ F increase in ADP temperature
  - Corrosion of carbon steel ductwork → additional insulation will not help
  - Solution → Increase air heater outlet gas temperature significantly, which may decrease combustion air temperature
- ▶ Plume opacity increase
  - Increased SO<sub>3</sub> may result in visible “blue” plume, esp for high-sulfur coals
  - Opacity limits may be exceeded → SO<sub>3</sub> removal system



- ▶ Ozone Season Only Operation
  - At 90% summer capacity factor → 3250 hours per ozone season, or ~6 year catalyst life
  - Most SCR units are in 2<sup>nd</sup> or 3<sup>rd</sup> ozone season now → half-way to spare (top) catalyst layer addition
- ▶ Year-round Operation
  - At 75% annual capacity factor → 6500 hours per year, or ~ 3 year catalyst life
  - 1<sup>st</sup> catalyst layer replacement soon after year-round operation begins



## ► Base Case

- 4 catalyst layer SCR, with initial fill of 3 lower levels → 3.0 total initial activity with 0 ppm slip
- Top layer has most catalyst deactivation → assume 50% at end of catalyst life
- Other layers degrade at ~half the rate of top/most active layer

## ► Spare Layer Addition (top layer)

- Before addition of spare layer → ~2.1 catalyst activity with 2 ppm NH<sub>3</sub> slip
- After Addition → 3.1 activity with no NH<sub>3</sub> slip



- ▶ 1<sup>st</sup> Layer Replacement
  - 2<sup>nd</sup> layer from top
  - Before replacement → 1.5 catalyst activity with > 2 ppm NH<sub>3</sub> slip, based on condition of spare layer addition
  - After addition → 2.3 catalyst activity with ~1.5 ppm NH<sub>3</sub> slip
- ▶ Regardless of the deactivation rate assumptions, with the 1<sup>st</sup> layer replacement the NH<sub>3</sub> slip will:
  - Before replacement → exceed 2 ppm, for the nominal catalyst life
  - After replacement → start at > 1 ppm NH<sub>3</sub> slip



- ▶ Thermal – sintering > 750 F
- ▶ Ammonia-sulfur compounds (ABS) – clogs pores, at low gas temperatures
- ▶ Alkaline metals (Na, K) – water-soluble form is highly mobile, resulting in ion exchange with active sites → esp during shutdowns
- ▶ Alkali earth metals – reacts with SO<sub>3</sub> → catalyst surface masking/blinding
- ▶ Heavy metals (arsenic, lead, nickel, etc) – poisons active sites
- ▶ Liquids – condensation in the pores acts as carrier of poisons & flashing during rapid thermal changes → cracking





► Conventional Hybrid

- In-duct SCR (single layer) – located between economizer outlet & air heater inlet
- Higher gas velocities with horizontal gas flow → problem with fly ash deposition
- Limited commercial application

► New Approach – “conceptual”

- Conventional, full size SCR with less catalyst layers → 2 layers
- SNCR optimum NO<sub>x</sub> removal~ 50% with very high NH<sub>3</sub> slip → 0.2 lb/Mbtu
- SCR removal ~70% → 0.05 lb with < 1 ppm slip
- SCR's SO<sub>3</sub> reduced with fewer catalyst layers



- ▶ Capital (\$/ton NOx removed)
  - SCR → 850
  - Hybrid → 1,000
- ▶ Operating (\$ per ton NOx removed)
  - Ash disposal – off-site disposal of NH<sub>3</sub> contaminated ash → Hybrid credit of 265
  - Replacement Power – lower pressure drop from less Hybrid catalyst layers → Hybrid credit of 25
  - Urea – higher urea consumption for Hybrid → Hybrid debit of 50
- ▶ Net Cost → Hybrid (\$760) less than SCR (\$850), if off-site contaminated ash disposal is required



▶ NH<sub>3</sub> slip

- 2 ppm NH<sub>3</sub> slip will eliminate byproduct fly ash sales
- 2 ppm will result in air heater pluggage for high sulfur coals
- Much over 1 ppm may be an operating concern

▶ SO<sub>3</sub> Emissions

- 4 catalyst layers “doubles” the boiler SO<sub>3</sub>
- Low-sulfur coal to high-sulfur coal with SCR+FGD → significant increase in ADP corrosion

▶ Economics

- New hybrid has higher capital cost than SCR
- Operating savings or avoided costs from lower NH<sub>3</sub> slip & SO<sub>3</sub> emissions than SCR



- ▶ Determine the “fate” of  $\text{NH}_3$  slip &  $\text{SO}_3 \rightarrow$  as the flue gas goes thru the air heater, ESP & FGD
- ▶ Measure the catalyst activity of each layer on a regular basis  $\rightarrow$  correlate total catalyst activity with  $\text{NH}_3$  slip as a function of time
- ▶ Determine the best method to off-set the increased ADP corrosion